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A Model For The Development Of Cargo Terminal Infrastructure And Smart Logistics Based On Multimodal Connectivity At Bijb Kertajati

[*]Hafizh Sabda Adhiaska, Dini Rosmalia[2], Wahyu Dewanto[3], Sandy Lesmana[4]
[1,2,3,4]Infrastructure and Enviromental Engineering, Faculty of Engineering, Pancasila University, South Jakarta, DKI Jakarta 12630
[*)]Corresponding autor: hafizhsa57240001@univpancasila.ac.id

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Abstract

West Java International Airport (BIJB) Kertajati has strategic potential as a regional logistics distribution hub, supported by its connectivity to toll roads, industrial zones, and the Rebana metropolitan development. However, low levels of flight activity and kargo distribution have resulted in suboptimal utilization of the area. This study aims to identify the current state of multimodal logistics infrastructure and analyze the need for smart logistics infrastructure development in the BIJB Kertajati area. This study employs a quantitative-qualitative approach (mixed-methods) using Gap Analysis and SWOT analysis, reinforced by the IFAS-EFAS framework. Research data was collected through field observations, literature reviews, and an analysis of the area's development policies. The results indicate that the BIJB Kertajati area possesses key strengths, including connectivity via the Cipali and Cisumdawu toll roads, the availability of extensive land, and a strategic location relative to industrial zones and the Port of Cirebon. However, the area still faces limitations, including low kargo activity, suboptimal multimodal integration, and limitations in the digital logistics system. The study produced a logistics infrastructure development model based on a kargo terminal, smart warehouse, digital logistics platform, and green infrastructure to support the efficiency of goods distribution and the sustainability of the area. This study is expected to serve as a reference for the development of airport-based logistics areas in Indonesia.

Keywords: *BIJB Kertajati, Cargo terminal, Logistics infrastructure, Smart logistics*

INTRODUCTION

The growth of global trade has increased the need for efficient, fast, adn integrated goods distribution system [1][2]. Logistics infrastructure is a critical element in supporting supply chain efficiency as it is directly linked to distribution costs, delivery times, and international trade connectivity [3][4]. Countries with modern logistics systems tend to be more competitive in supporting industrial growth and investment.

In the Indonesian context, national logistics costs remain relatively high compared to other countries in Southeast Asia [5]. This is based on calculations by the National Development Planning Agency (Bappenas) and the Ministry of Transportation, which indicate that Indonesia's domestic logistics costs range from 14.29% to 14.90% of gross domestic product- a figure that remains among the highest in the ASEAN region, where the average for developed nations stands at 8% to 9%. This situation has prompted the government to develop new logistics distribution centers based on multimodal connectivity to improve national distribution and strengthen the regional supply chain [6]. One area with strategic potential is the West Java International Airport (BIJB) Kertajati.

BIJB Kertajati was built as part of a national strategic project to alleviate congestion at Soekarno-Hatta International Airport while accelerating economic growth in eastern West Java [7][8]. The airport is supported by connectivity via the Cipali and Cisumdawu toll roads, which improve distribution access to Jakarta, Bandung, and Cirebon [9]. Additionally, the area's location is relatively close to the Port of Cirebon, thereby potentially supporting a multimodal logistics distribution system integrating air and land transport [10]. Nevertheless, cargo distribution activity at BIJB Kertajati remains relatively low. Cargo terminal infrastructure, digital warehousing systems, and digital logistics integration have also not yet developed optimally. These conditions mean that the airport-based logistics area has not yet been able to fully support regional distribution [11].

The development of airport-based logistics zones has been successfully implemented in several countries, such as Incheon International Airport in South Korea and Schiphol Airport in the Netherlands. These zones have evolved into global distribution hubs, supported by modern cargo terminals, automated warehouses, and digital logistics systems integrated with multimodal transportation [3]. Incheon International Airport has successfully developed smart logistics based on an automated cargo handling system and digital freight management, thereby enhancing the efficiency of international goods distribution [12]. Compared to these areas, BIJB Kertajati still faces limitations in logistics infrastructure and goods distribution integration, necessitating the strengthening of cargo terminals, smart warehouses, and an integrated digital logistics platform.

Smart logistics is a promising solution for addressing the numerous stages and operational costs of logistics[13]. These findings align with [11] who concluded that digitalization in logistics can improve distribution efficiency, reduce delivery distances, and lower the risk of errors; however, previous studies have not yet documented the implementation of smart logistics at airports. Additionally, intermodal transportation in logistics can reduce costs by up to 30% through route optimization, cargo consolidation, and travel time efficiency [11].

Figure 1. Smart Logistics

As shown in Figure 1[13], Internet of Things (IoT) technology, big data analytics, and AI-which can be applied in smart logistics share four common characteristics, namely

1. Intelligence. Smart technologies such as AI, automation, information, and communication are applied to all or most logistics processes to increase the level of automation in logistics operations and enable intelligent decision-making regarding logistics management issues.
2. Flexibility. Smart logistics offers a higher level of flexibility to accommodate more accurate demand, better inventory optimization, and more efficient transportation routes.
3. Logistics integration. Through the use of technologies like IoT, information sharing across logistics sectors can be realized, and related processes can be managed centrally, thereby strengthening coordination.
4. Self-organization. Real-time monitoring and intelligent decision-making allow the logistics system to function with minimal human intervention, which indirectly improves the efficiency of logistics operations.

This indicates that most prior research has generally addressed aerotropolis, smart logistics, and multimodal systems separately.

This study addresses this gap by integrating aerocity, smart logistics systems, and multimodal transport into a single integrated development model for the development of smart logistics-based multimodal logistics infrastructure in the BIJB Kertajati area. Therefore, this study proposes a logistics infrastructure development model focused on cargo terminals, smart warehouses, digital logistics platforms, and multimodal connectivity within a single regional distribution system.

The presence of cargo terminal infrastructure, smart warehouses, and digital logistics can support the efficient distribution of goods in the BIJB Kertajati area. The cargo terminal serves as a facility for receiving and unloading cargo from aircraft, which is then forwarded to the smart warehouse tasked with optimizing space management, accelerating the sorting process, and minimizing human error. To integrate data received from the cargo terminal and inventory data from the smart warehouse into a single, real-time, transparent integrated system using a Digital Logistics Platform. Furthermore, goods can be shipped using the appropriate intermodal transport options due to multimodal connectivity. This study aims to identify the existing conditions of multimodal logistics infrastructure in the BIJB Kertajati area and subsequently analyze the need for smart logistics infrastructure development to support regional and national goods distribution.

In assessing the current state of infrastructure against the ideal standards for an airport as a smart logistics hub, the following indicators can be used [14][3][15]: First, toll road infrastructure is analyzed with a focus on distribution connectivity. To measure its success, the assessment indicators used include direct accessibility to the cargo area and aerocity, travel time efficiency, and the capacity of the toll road itself. Next, regarding cargo terminals, the analysis focuses on air logistics activities. The evaluation of this infrastructure is measured through aspects such as capacity, processing speed, and the comprehensiveness of available facilities.

Meanwhile, for modern infrastructure such as smart warehouses, the analysis focuses on warehousing systems, which are evaluated based on the level of warehouse automation, digital warehouse integration, and layout efficiency. On the other hand, digital logistics centers its analysis on tracking and distribution. Assessment indicators include technology utilization and the level of data integration across sectors.

Finally, there is multimodal connectivity infrastructure that links airports, toll roads, and ports. The analytical focus for this component is assessed based on the completeness of supporting infrastructure and the level of synchronization of intermodal transit times. First, toll road infrastructure is analyzed with a focus on distribution connectivity. To measure its success, the evaluation indicators used include acc.

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METHOD

A. LOCATION

The subject of this study is the Kertajati area, Kertajati Subdistrict, Majalengka Regency, West Java, Indonesia, which is currently designated as one of the national strategic projects. The focal point of this area is the Kertajati West Java International Airport (BIJB) and its surrounding area, which is designed as Kertajati Aerocity. The Kertajati area is referred to as the "golden triangle" due to the presence of BIJB, the Cipali Toll Road, and the Cisumdawu Toll Road, making this area suitable as a location for the development of a smart logistics-based airport.

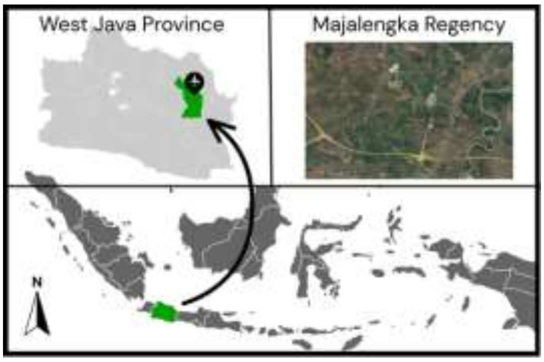

Figure 2. Lokasi Penelitian

B. DATA PROCESSING

This study employs a mixed-methods approach, focusing on a case study of the BIJB Kertajati area in West Java. Research data was collected through field observations, literature reviews, and area documentation. Observations were conducted to identify the current state of logistics infrastructure, the accessibility of goods distribution, and the cargo system in the vicinity of BIJB Kertajati.

A Gap Analysis was used to analyze the existing conditions of the multimodal logistics infrastructure in the BIJB Kertajati area, which was then compared to the ideal standards for the implementation of smart logistics infrastructure.

Table 1. Smart Logistics Infrastructure Indicators

Types of Infrastructure	Focus of Analysis	Assessment Indicators
Infrastruktur jalan tol [6]	Distribution connectivity	• Direct accessibility to cargo and aerocity areas • Travel time efficiency • Toll road capacity
Toll road infrastructure [15]	Air logistics activities	• Capacity • Process speed • Completeness of facilities
Smart warehouse [14] [16]	Warehousing system	• Warehouse automation level • Digital-based warehouse integration • Layout efficiency
Digital logistics [14]	Tracking and distribution	• Utilization of technology • Level of data integration between sectors
Multimodal connectivity [6] [3]	Airport, toll road, port	• Infrastructure completeness • Transit time synchronization level

Table 1 shows the indicators for the development needs of the BIJB Kertajati smart logistics zone. Next, calculations are needed to determine the gap between the current situation and the ideal standard using the following formula.

$$GAP(\%) = \frac{Ideal\ Score - Exixting\ Score}{Ideal\ Score} x100 \quad (1)$$

Furthermore, to answer the second objective of the study, a SWOT (Strengths, Weaknesses, Opportunities, dan Threats) analysis was used which was strengthened using the IFAS (Internal Factor Analysis Summary) and EFAS (External Factor Analysis Summary) approaches to measure the level of influence of internal and external factors on the development of BIJB Kertajati's logistics infrastructure.

C. Limitations Section

This study has several limitations. First, the actual cargo volume data at BIJB Kertajati still relies on secondary data because airport operations have not yet fully stabilized in the post-pandemic period. Second, the assessment using the IFAS-EFAS matrix remains subjective because it relies on the opinions of a panel of experts. Finally, since this study focuses only on the Rebana area and BIJB Kertajati, the proposed model cannot be directly applied to other airports. Parameter adjustments and further testing will be necessary if it is to be used at airports with different regional characteristics.

RESULT AND DISCUSSION

A. Existing Condition of the Kertajati Area

The Kertajati BIJB area is strategically positioned to support regional logistics distribution due to its connection to the Cipali and Cisumdawu Toll Roads, which connect the area to Jakarta, Bandung, Cirebon, and industrial areas in West Java [9]. Furthermore, the area's proximity to the Port of Cirebon strengthens the potential for developing a multimodal distribution system based on air and land[3]. These conditions indicate that Kertajati BIJB has significant potential to develop as an airport-based regional logistics distribution center.

Figure 3. BIJB Kertajati Multimodal Logistics Infrastructure Connectivity

Figure 3 shows the integration of connectivity within the Kertajati BIJB area with the Cipali and Cisumdawu toll road networks, the Port of Cirebon, approximately 60 km from the airport, and the industrial area supporting multimodal logistics distribution. This demonstrates that the Kertajati BIJB area already has adequate basic infrastructure support. However, there are other factors that contribute to the development of a smart logistics area within the Kertajati BIJB area.

Table 2. Gap Analysis of Smart Logistics in the BIJB Kertajati Area

Assessment Indicators	Existing Conditions	Ideal Standard	Points
Direct accessibility	Already connected via the Cipali and Cisumdawu Toll Roads directly to the airport gates.	Unhindered access	4
Travel time efficiency	Travel time is reduced due to the toll road	Minimum travel time	4
Toll road capacity	Traffic jams rarely occur	Capable of accommodating large load volumes without reducing modular speed.	5
Capacity	Capacity is sufficient for now but utility is still not optimal	Sufficient capacity	3
Kecepatan proses	The handling process is still manual	Fast handling process	3
Completeness of facilities	Mandatory facilities (X-Ray, quarantine area) are available,	Modern supporting facilities are available	2

Assessment Indicators	Existing Conditions	Ideal Standard	Points
	but supporting facilities such as cold storage are still limited.		
Warehouse automation level	The majority still rely on human power	Using AGV (Automated Guided Vehicles) or similar	2
Digital-based warehouse integration	Recording is still manual and not yet integrated in real-time	*Automatically connected Management System (WMS)*	3
Layout efficiency	The arrangement of goods is still conventional based on space availability.	Dynamic layout based on the frequency of goods in and out	2
Utilization of technology	The tracking system still uses standard barcode scanning.	Implementation of IoT, RFID, or Barcode scanner	*2*
Level of data integration between sectors	The customs system (Customs) is online, but the data exchange system between airlines, agents and land transportation is still separate.	*Integrated Single Submission/Cloud Platform System*	*3*
Infrastructure completeness	The integration of air (airport) and land (toll road) modes is already underway, but the Logistics Railway (KA) line has not yet been built.	There is integration between air, toll roads and logistics trains.	3
Transit time synchronization level	The time lag for moving goods is still fluctuating because the schedule is not yet digitally integrated.	*Minimum interchange time; arrival schedule of trucks, trains, and planes*	2

This standard is rated on a scale of 1 to 5, with the highest score indicating that the standard has been met to the ideal level. Table 2 concludes that the toll road infrastructure is quite adequate, but the technology-based logistics operational support infrastructure still has many shortcomings. The following calculations were performed to determine the total gap value against the ideal standard for smart logistics areas in the BIJB Kertajati area.

$$GAP(\%) = \frac{65-38}{65} x100 \rightarrow 41\%$$

Based on the analysis results, the gap value is 41%, where the current warehousing system still relies mostly on manual labor and lacks the role of smart mechanism systems.

B. Cargo Terminal Infrastructure and Goods Distribution Needs

Furthermore, to address the second objective, a SWOT analysis was used to identify internal and external factors influencing the development of BIJB Kertajati's logistics infrastructure as a smart logistics hub based on multimodal connectivity. The analysis focused on the development of cargo terminals, logistics distribution, smart warehouses, and digital logistics integration to improve the efficiency of the region's supply chain[9].

Strengths

The BIJB Kertajati area's primary strength lies in its transportation infrastructure connectivity, supported by the Cipali and Cisumdawu Toll Roads. This infrastructure improves access to goods distribution to Jakarta, Bandung, and industrial areas in West Java. Furthermore, the availability of extensive land and the area's proximity to the Port of Cirebon are supporting factors for the development of multimodal logistics distribution.

Weaknesses

The area's primary weaknesses lie in the low activity of cargo terminals and the suboptimal integration of smart logistics. Warehousing infrastructure remains conventional and is not supported by digital-based smart warehouses. Furthermore, digital logistics platforms and tracking systems are still limited, resulting in a lack of real-time and integrated distribution of goods.

Opportunities

The growth of e-commerce and the need for fast distribution create significant opportunities for the development of smart logistics in Indonesia. Furthermore, the relocation of industry from Greater Jakarta (Jabodetabek) to eastern West Java offers the potential for increased industrial investment in the Kertajati area.

Threats

Competition with other logistics areas in Indonesia poses a challenge to the development of Kertajati as a regional distribution hub. Furthermore, delays in the development of cargo infrastructure and multimodal integration have the potential to hamper the efficiency of regional logistics distribution.

Weighting with IFAS and EFAS is done based on the level of importance of each factor to the development of cargo terminals, smart warehouses, digital logistics, and multimodal connectivity. Matrix weights were determined using the Delphi Method, which involved five experts (two logistics scholars, one airport practitioner, and two infrastructure scholars) through two rounds of anonymous questionnaire iterations. Consensus validation was measured using the degree of convergence of opinions among the experts, thereby yielding an objective assessment free from the dominance of any single opinion, as often occurs in face-to-face interactions.

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \quad (2)$$

Where X_i is the weight assigned by the i-expert, and n is the total number of experts (n=5).

Table 3. BIJB Kertajati Logistics Infrastructure IFAS Matrix

Internal Factors	Quality	Rating	Skor
Connectivity of the Cipali and Cisumdawu Toll Roads	0,20	4	0,80
Availability of logistics land	0,15	4	0,60
Strategic position of the area	0,15	3	0,45
Cargo activity is still low	0,20	2	0,40
Smart warehouse is not yet optimal	0,15	2	0,30
Limited digital logistics	0,15	2	0,30
Total	**1,00**		**2,85**

Table 3 shows that the BIJB Kertajati area's main strengths lie in its infrastructure connectivity and the availability of land for logistics development. However, the area still faces weaknesses in cargo activities and smart logistics integration.

Calculation of coordinate values based on the IFAS matrix results yields

Total Strength Score:
0.80 (toll) + 0.60 (land) + 0.45 (location) = 1.85
Total Weakness Score:
0.40 (Low Cargo) + 0.30 (Warehouse) + 0.30 (Digital) = 1.00

X-Axis Coordinate = Strength - Weakness = 1.85 - 1.00 = +0.85

Table 4. BIJB Kertajati Logistics Infrastructure EFAS Matrix

Internal Factors	Quality	Rating	Skor
Growth of the logistics industry	0,25	4	1,00
Increased e-commerce activity	0,20	4	0,80
Development of the Rebana area	0,20	3	0,60
Competition in logistics areas	0,15	2	0,30
Risk of infrastructure delays	0,10	2	0,20
Regional environmental risks	0,10	2	0,20
Total	**1,00**		**3,10**

The coordinate values calculated using the EFAS matrix results are as follows:

Total Opportunities Score:
1.00 (Industry) + 0.80 (E-commerce) + 0.60 (Rebana) = 2.40
Total Threat Score:
0.30 (Competition) + 0.20 (Infrastructure Delays) + 0.20 (Environment) = 0.70

Y-axis Coordinate = Opportunities - Threats = 2.40 - 0.70 = +1.70

Based on the IFAS and EFAS analyses, The SWOT coordinates (+0.85,+1.70) were obtained. These coordinates place the BIJB Kertajati logistics area development model in Quadrant I (Aggressive Strategy/Growth-Oriented). The Kertajati International Airport (BIJB) area has strong potential for developing logistics infrastructure, enabling development strategies to focus on strengthening cargo terminals, smart warehouses, and integrated multimodal distribution connectivity.

This growth rate is consistent with modern airport-centered development models, which emphasize that the expansion of airport logistics hubs must aggressively leverage regional infrastructure during their growth phase to attract global supply chains [17]. Furthermore, the urgency to scale up BIJB Kertajati's cargo terminal capacity mirrors the findings of Ying Xi al. [18] who argued that modern air cargo hubs require immediate infrastructure expansion and digital readiness to prevent operational bottlenecks and enhance regional supply chain resilience.

Cargo terminal development should focus on increasing goods distribution capacity, integrating digital logistics systems, and developing multimodal air freight logistics. These infrastructure improvements are necessary to accelerate the flow of goods and support the efficiency of the regional supply chain.

This smooth distribution process relies on real-time data integration through an IoT Tracking System and Digital Logistics Platform. These systems are expected to facilitate goods monitoring and decision-making without requiring extensive human intervention. Smart warehouse development is necessary to improve the efficiency of goods distribution and digital-based supply chain management [4].

The identified 41% gap caused by cargo handling that is still done manually can be addressed through the implementation of smart technologies, in line with the research by Lee et al. [19]. Their study shows that the implementation of IoT tracking systems and automated warehousing systems significantly reduces human error, optimizes space utilization, and shortens processing time. Furthermore, the integration of a Digital Logistics Platform for real-time data sharing reinforces the conclusions of Booi Kam et al. [20] who noted that cloud-based digital platforms are the backbone of modern logistics centers, enabling seamless multi-party collaboration and agile operational decision-making.

CONCLUSION

The gap analysis results show a gap of 41%. The gap is particularly pronounced in the warehousing system, which currently relies on manual labor and lacks the role of intelligent mechanisms. However, several indicators indicate the area is approaching ideal standards, such as adequate road access and short travel times.

The SWOT analysis indicates that the Kertajati BIJB area has strategic potential to develop as a smart logistics hub based on multimodal connectivity in West Java. The Cipali Toll Road, the Cisumdawu Toll Road, and access to the Port of Cirebon are key factors in supporting regional and international logistics distribution. This strategic reliance on highway networks and maritime access exemplifies contemporary multimodal integration theories. Modern transport geography dictates that the success of an airport logistics hub depends heavily on its 'hinterland connectivity' and its capacity to function efficiently as a trimodal (air-sea-land) node [3]. Similar empirical evidence by Guo Liquan et al. [21] confirms that tightly connecting airports with nearby seaports and toll networks drastically minimizes total logistics costs and accelerates macro-regional economic growth.

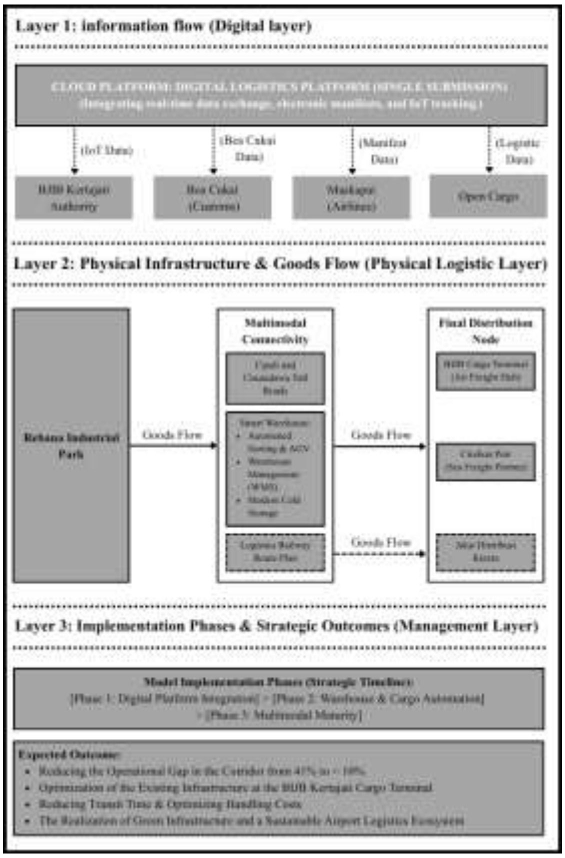

Figure 4. Conceptual Diagram of the Development Model

Figure 4 presents the comprehensive conceptual model proposed for the development of the BIJB Kertajati logistics zone, directly addressing the 41% operational gap identified in the study. Unlike generic supply chain frameworks, this model integrates multi-tier operational dimensions specific to the Kertajati Aerocity ecosystem. The top layer establishes the institutional information flow, where a Cloud-based Digital Logistics Platform synchronizes data between customs, BIJB authorities, airlines, and land transport agents, addressing the current lack of real-time sector integration. The physical layer conceptualizes the goods flow from the Rebana industrial zones through the Cipali and Cisumdawu toll infrastructure into a digitized Smart Warehouse equipped with automated sorting and WMS.

Finally, the implementation phases dictate a structured three-step deployment (System Integration → Automation Upgrade → Multimodal Maturity) aimed at achieving the expected outcomes: maximizing airport cargo utility, minimizing transit time, and establishing green logistics sustainability

Therefore, recommendations for regional development should focus on improving cargo terminals, developing smart warehouses, and integrating digital logistics to increase the efficiency of goods distribution. The logistics infrastructure development model developed in this study is expected to serve as a reference for developing airport-based logistics areas in Indonesia.

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